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ON

SCIENTIFIC EDUCATION;

BY

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ON SCIENTIFIC EDUCATION.

As the subject of scientific education is now occupying some attention in this country, a few remarks respecting science, the mode of teaching it, and the qualities desirable in a teacher, may be permitted; the remarks apply more particularly to physics and chemistry.

The belief that scientific knowledge is not sufficiently diffused in this country has now become rather general, and is rapidly extending, but the causes of this want of diffusion are much less understood. There are several reasons why science is not well understood in England, and they are connected together. The application of our great store of power in coal, to manufacturing and other purposes, has developed our commercial energy to an immense extent, and enabled us to acquire an enormous amount of wealth; and this great pecuniary success has caused us to attribute a greater value to money than to knowledge; and, combined with our insular position, has also caused us to undervalue the opinions and progress of other nations with regard to scientific education. Science is much less honoured in this country than on the continent of Europe, especially in Germany; here a man of science is thought but little of unless he is a man of money. Another reason is, most parents who send their sons to the Universities and large schools of this country, not having been themselves educated in science, do not properly understand its advantages, and therefore do not specially wish their sons to learn it; further, nearly all the honours and endowments at the Universities have been bestowed upon other subjects than those of physics and chemistry; these sciences, in their most important developments, are modern subjects, and the endowments of the Universities, being chiefly of older date, are therefore not devoted to their encouragement. It is well known at Oxford, and to those acquainted with that University, that numerous fellowships and advantages are conferred upon comparatively unworthy recipients in other subjects, which might with great benefit to the nation be devoted to the encouragement of physical and chemical science. The want of a fair share of encouragement of these subjects in our Universities and large schools, is also connected with the fact that the governing bodies of those Universities and the head-masters of those schools have been largely unacquainted with physical and chemical science. It is well known amongst scientific men, and is fast becoming known to the public in general, that neither of our old Universities are as eminent in these subjects as in classical and mathematical learning. Our Universities, instead of being in the front rank of advance in *all* kinds of theoretical knowledge, as such seats of intelligence are properly expected to be, have been behind the times in these subjects; they are, however, now making some attempts to remedy this defect. Many head-masters of schools are also highly aware of the importance of science and the desirability of teaching it, and are doing all they can to promote it.

Sir R. B. C. Brodie, Professor of Chemistry at Oxford, speaking of his experience when a student at Geissen, in Germany, states: "I say that the enthusiasm and earnestness of the young men in the laboratory was quite unparalleled in my experience at Oxford. The dillettante sort of way in which things go on there is very inferior indeed to the way the German students study. At Heidelberg, I have been told, there are about eighty professors, and amongst those professors are some of the most eminent men in Europe, so that they have a staff quite unsurpassed. The contact with such men creates an enthusiasm for knowledge." In the "Report of the Royal Commission on certain Schools and Colleges," page 32, 1864, the Commission says: "Natural science, with slight exceptions, is practically excluded from the education of the upper classes in England. Education with us is in this respect narrower than it was three centuries ago."

It must not be supposed, from these remarks, that no progress has been made in the introduction of science into our Universities and large schools. Two members of the Council of the Royal Society have been appointed Governors of Rugby and Shrewsbury Schools, and two others have been nominated as such for Eton College and Westminster School, in accordance with the new Act af Parliament. At Oxford, Eton, and Rugby, laboratories and lecture rooms for science have been newly erected, at considerable expense. Several fellowships have recently been given for merit in natural science at Oxford and Cambridge. A number of scholarships and exhibitions are just now offered for proficiency in science at Oxford and Cambridge, and at St. John's College, Cambridge, "natural science is on the same footing as classics and mathematics, both as regards teaching and rewards." At Rugby School, natural science is a part of the regular school work; out of 500 boys about 360 receive instruction in science, and a portion of this latter number are compelled to receive such instruction. At Cambridge it is said there is a want of students in natural science, not of teachers; "the lectures are insufficiently attended;" "the class from whom the University is recruited is behind the age." In these various ways much has been done, but an immense amount still remains to be accomplished. Notwithstanding these statements, the neglect of science in this country has been very general, pervading nearly all classes of society; it has also been long continued. The evil has existed for a generation past, and will take many years to be remedied. The remedial changes which are being made in our educational institutions are as yet only partial, and not at all proportionate to the magnitude of the evil; the changes already made are also quite recent, and have not yet had time to produce much effect. Meanwhile, the public is beginning to feel alive to the great neglect of science, and many person occupying responsible positions in our old Universities, and who feel the influence of public opinion, are anxious to show that they are now desirous of recognising science as a branch of education.

Through want of scientific education in our great Universities, many men who have been educated there look upon science as a degrading menial pursuit, and in various ways entertain ignorant notions respecting it. Some University teachers look upon chemistry as a kind of apothecary's shop affair, and that the analytical chemist has only to mix the substances and he will be able at once to tell how much there is of each ingredient present. In consequence of their want of experience in physical science, some of them ridicule the idea that the proper use of physical apparatus requires considerable experience; it has been remarked to me, by a teacher from one of our old Universities, that "such an idea is contemptible." It is a general and widespread fallacy of the minds of men unexperienced in science, to consider the phenomena of nature to be much more simple than they are. Faraday himself frequently noticed this.

Many of those teachers who have been educated at the old Universities of this country have an idea that only themselves are competent to teach science, and the head-masters of some of our large schools have carried this ignorant principle so far as to encourage the teaching of scientific subjects by University men comparatively inexperienced in science, and to discourage such instruction by scientific teachers of established repute.

Two of the chief reasons why physical and chemical science have not been, and still are not, adequately encouraged in many of our large schools are, first, the majority of head-masters, not having been educated in such subjects, have not been able to properly appreciate their degree of importance in developing the intellectual powers, or their great value in relation to manufacturing, artistic, agricultural, and other operations, and are not practically acquainted with all the proper methods and conditions of teaching them; and, second, the head-masters have only been able to obtain the greatest amount of repute by sending as many classical scholars as possible to the Universities. Even where the teaching of science has been introduced into some of our large schools, it is still in many cases treated as a subject of quite a secondary degree of importance, and is not accorded that degree of respect which is accorded to classics and some other subjects; in some cases it is relegated to the holiday portions of the week, and is sacrificed to cricket and other less important occupations; in other instances the teaching is only occasional, and the proportion of boys taught is very small. In some large schools, also, the name of the scientific teacher is not published in the school list with the names of the other masters, and thus science is degraded, and the teacher of it is prevented from obtaining the full credit of his successful teaching.

The amount of really intelligent interest in science exhibited by persons in general in this country is remarkably small; many persons express wonder at the results of modern science, but few understand them; few persons learn sufficient of science to be able to use intelligently such knowledge. Through an ignorance of science our statesmen have neglected its encouragement until now our loss of trade is pressing it upon their notice. Manufacturers have neglected it, until now they find that foreign workmen excel our own. Many ministers of religion have considered science in a large degree a hostile subject, and have used their powerful social influence to detract from its value. Many also have preferred the study of the pagan authors of classical literature, and have ignored the study of the works of God in nature. "Statesmen, heads of colleges, and ministers of religion have devoted the most important part of their educational life to the study of classics, and have left the universe of matter and science nearly a blank in their knowledge."

Is not the world of matter as extensive as the world of mind? and is not the study of science as important as the study of classics? Science is as large as the Universe, and a knowledge of it is at least as essential to the well being of mankind as a knowledge of literature. The essential parts of a well-balanced education consist not only of the expression of thought by means of language, but also the training of the powers of observation by means of scientific phenomena, and the exercise of the reasoning faculties upon cause and effect by means of a large store of scientific ideas. Science supplies us with accurate ideas, and language enables us accurately to express them, and therefore both are essential in any scheme of general education. Science is largely the basis of language; without a large and varied stock of scientific ideas, language is comparatively empty and inaccurate, and hence a fluent classical man can make a ready but unreliable speech. Without embodying our thoughts in accurate language we cannot speak or write with freedom, and we cannot so effectually reason, and, therefore, a man who is learned in science, but undisciplined in language, cannot freely communicate his store of knowledge. The obligations of science to language are great and numerous, and so also are those of language to science. It is only by means of thorough scientific training that men are able to perform the highest intellectual feats of which the human mind is capable, viz., the making of new and important scientific discoveries; the most perfect possession of a knowledge of language alone would not have enabled Newton to perform so sublime a feat as the discovery of the law of universal gravitation.

Natural science is as powerful a means of developing the mind as is the study of classical languages: it is evident, therefore, that those who have the direction of large educational establishments should be learned in the one subject as well as in the other, otherwise they will probably entertain a prejudice against the study of the subject with which they are least acquainted. It is as inappropriate for unscientific persons to have the direction of scientific instruction, as it would be for persons ignorant of classics to direct classical education; and it cannot reasonably be expected that the scientific education of this country will acquire its proper position whilst so many head-masters of our schools are comparatively ignorant of science. Misdirected superintendence is worse than none. "There is no instance on record of an active ignorant man who, having good intentions and a supreme power to enforce them, has not done far more evil than good." To obviate the difficulty of procuring for large schools, head-masters possessed both of classical and scientific knowledge, it has been suggested in some cases to divide each large school into literary and scientific departments.

The members of our Governments have also largely neglected to encourage scientific education, almost entirely because they have not been educated in scientific subjects, and have consequently not been able to appreciate their great national value; but since the recent progress of foreign competition has begun seriously to affect British industry, their attention has been drawn towards the subject, and a Royal Commission is now enquiring into the degree of encouragement of science and of science education in this country. It has been publicly stated that it is rare to find an English Cabinet Minister possessed of even a moderate amount of knowledge of physics or chemistry.

The aristocracy of this country have also shown but very little encouragement to scientific education, although in many instances the value of their estates has been largely increased in consequence of the development of new manufactures and of railways by means of science. The numerous researches on the latent heat of water, the tension of steam, the mechanical effect of heat, the strength of iron, &c., contributed to the production of the steam engine and modern machinery; the discovery of chlorine by Scheele gave rise to the modern process of bleaching, and to many improved methods of dyeing textile fabrics; and those methods, combined with others, produced the cotton manufacture, which gives employment to many thousands of persons, and has required the erection of numerous buildings, and greatly increased the value of building ground in Lancashire. Many other great advantages derived from science, in its application to agriculture, the discovery of minerals, and in other ways, by the upper classes in this country, might be readily mentioned.

It is a fallacious argument to say that progress of science and increased value of land are only remotely connected together; a cause as certainly produces its effect, however many connections lie between them, provided the connections are certain; the number of links in a chain makes no difference in the transmission of motion from one end of it to the other. Great causes are frequently distant and wide-spread in their effects; it might easily be shown that the area of the spots upon the sun influences the price of our bread. Persons in general can easily understand that an acorn planted in the ground will in the course of time become an oak, because it is a palpable and visible effect, but they cannot so readily perceive that the benefits resulting from a knowledge of science ramify through all our manufacturing, artistic, and commercial occupations, our social relations, and our every-day life, not because the dependence of our welfare upon science is less real, but simply because the connection between the two is less understood.

The advantages of science penetrate everywhere. Every man who eats his food with an electro-plated fork is indebted for the use of that article not only to the labours of those inventors who developed the steam-engine, by means of which the metal is rolled and stamped into forks, but also to Volta, Davy, and others, who produced the voltaic battery, to Guy Lussac, who discovered cyanide of potassium, and to the various inventors and practical men who applied all those means to produce the final result. We are all of us indebted for gas-light to the discovery of coal gas, and to Mr. Murdoch and others who applied that material to lighting. And we should none of us receive our letters with the speed and regularity we now do, had not Stephenson and others developed the locomotive steam-engine.

This nation largely subsists on the results of scientific knowledge, and the future success of this country is dependent upon science to a degree of which persons in general have but little conception. *Scientific progress is the great fountain-head of industry;* scientific discoveries form the basis of inventions, inventions produce improved arts and manufactures, and improved arts and manufactures lead to increased national prosperity. The discoveries of voltaic electricity, electro-magnetism, and magneto-electricity, by Volta, Oersted, and Faraday, led to the invention of telegraphy by Wheatstone and others, and to the great manufacturers of telegraph cables and telegraph wire, and the materials and apparatus used with them. It has also led to the employment of thousands of operators to transmit the telegraphic messages, and to a great increase in our commerce in nearly all its branches by the more rapid means of communication. The discovery of voltaic electricity further led to the invention of electro-plating, and to the large manufacture of electro-plated articles. By numerous additional examples it might be easily shown that the development of scientific knowledge has already resulted in the employment of whole armies of workmen, and in the expenditure of a fabulous amount of money, in railways, gas-works, manufactures, &c., in this country. It will cost hundreds of millions of pounds sterling to cover the whole earth with telegraphs, and thousands of millions to cover it with railways, and if these results are being produced by only the beginnings of science, what may be expected from its future development, especially if aided by systematic encouragement? The construction of English railways alone has been calculated to have already cost upwards of five hundred and seventy-six millions of pounds. The diminution of labour which sometimes occurs in consequence of the progress of science is extremely small compared with its increase; for instance, the number of waggoners and horses now employed, merely to collect and deliver all the goods for railways, is much greater than the whole of those employed for conveying all the goods of the country before railways were constructed. That many other influences, besides that of science, have contributed to the development of our manufacturing and commercial prosperity is also true, but it would be foreign to the subject of the present paper to point them out.

Although the progress of scientific knowledge has resulted in such universally diffused advantages, also in the employment of so many workmen, and in the production of such immense quantities of manufactured commodities, scientific education has not been sufficiently encouraged in this country to enable it to keep pace in commercial progress with continental nations, and especially with Germany. Our large manufacturers and men of business have accepted and employed the advantages of science in an endless variety of ways in their manufactures; trades, and occupations, and have thereby acquired immense wealth; but they have not sufficiently encouraged scientific education, nor sufficiently aided the class of men to whom those advantages are so largely due; that which has been the duty of all, has been attended to completely by none. "One man sows, and another man reaps," which is of course a very agreeable arrangement for the man who reaps; but it cannot last for ever. Manufacturers have willingly reaped the advantages of the labours of unpaid discoverers, but have not adequately sowed the means of future progress; Volta, Oersted, Faraday, and many other men, who, at great expense of thought, time, labour, and a considerable sum of money, discovered the chief facts and principles upon which many of the great modern applications of science are based, received no remuneration for those labours, and at the present time there is in this country absolutely no provision for the support of physical and chemical investigators, and thus the very fountain head of labour and of improvements in manufactures is kept exhausted. Such neglect is perfectly suicidal to the extension of our trades, and, combined with other causes, has already produced a marked effect in gradually transferring our manufactures to more scientific nations. As long as such neglect exists, so long must its injurious effect upon our manufactures and commerce continue; the cause and its effect are inseparable. If a moderate annual grant or payment of money for the purposes of original research was made by our Government (or by means of local effort) to each professor of science in the educational institutions throughout the country, and it was a condition of the appointment that such research should be made, a considerable amount of this national disgrace would be prevented, and the expenditure would be highly profitable to the nation. Whilst a multitude of other deserving objects are understood and aided either by the public or the State, original scientific research stands almost alone in receiving scarcely any encouragement. How can we expect to obtain new arts and manufactures, or make improvements in old ones, if new discoveries are not made in the properties of matter and its forces?

Original scientific research is a subject quite outside the experience and understanding of persons in general, and that is doubtless the chief reason why it has not in our own universities been endowed and encouraged like other subjects, the benefits of which are more generally understood. Nearly all persons look upon scientific discoveries as sudden happy accidents and fortunate ideas, which when once found are quickly developed, and do not look upon them in their true aspect, viz., as slowly developed results of life-long labours of the greatest difficulty, and of exertions of the very highest intellectual power, expended in the gradual extraction of truth out of extreme complexity of error.

Scientific men also have, more than any other class of men, neglected to enforce the just claims of their own subject, and the reason for this is, the pursuit of pure science is essentially less selfish than that of most other subjects; it is a spirit of the highest self-denial comparatively regardless of personal emoluments.

That physics and chemistry should form a part of the intellectual training of all intelligent men is manifest when we consider the effect they have upon the human mind. Every different kind of instruction has its own class of effects upon the mental faculties. The effects of thorough scientific instruction are to make the mind powerful and accurate in observation, thought, and expression in all that relates the physical and chemical phenomena of the material universe; it also greatly developes and strengthens the judgment in relation to material phenomena, in reasoning on their nature, causes, operations, and effects. By developing the faculties of observation in such matters, in imparts great pleasure in noticing the ordinary phenomena of nature, and also in observing the phenomena presented by manufacturing, artistic, and other operations. Many persons, not having been taught science, or how to observe, can neither effectually enjoy nor be adequately benefitted by examining the phenomena of nature, or by the inspection of industrial operations; "they are like blind men set to behold beautiful scenery." By developing the reason it enables us to distinguish truth from error in reasoning on the facts of nature. All men profess to reason, and many think they reason in science when they only talk about it; those reason most correctly in it who are disciplined in the study of the exact and experimental sciences. The most common intellectual defect of the so-called educated part of this nation, and to which especial attention was called by Faraday, is deficiency of judgment and reasoning power in questions relating to matter and its forces, and this defect has arisen from the want of scientific instruction in our leading achools; we meet with many persons, otherwise intelligent, who believe in various supernatural agencies, who, if they had been educated in science, would readily see the inconsistency of such beliefs with well-verified scientific knowledge. Such persons are frequently credulous where they should be sceptical, and incredulous where they should believe.

The relation of scientific knowledge to the human mind is such that the possession of it is accompanied by the desire for more; a man who has it not does not usually wish to possess it, and only those who have acquired it can at all adequately estimate its value in improving the mind.

One great difference between science and the ordinary subjects of education, is the great feature of *progress* which it possesses. Its principle is not only to work, but also to improve and advance, and this principle ("Forward") pervades and animates all its teaching. Education in science is rapidly being enlarged in its boundaries by newly acquired knowledge. "Science always presents new information to be acquired, new objects of study, new facts and laws to be discovered, new inventions to be made, new difficulties to be overcome; and is therefore an inexhaustible source of mental discipline." In science, however much we may learn, there still remains something undiscovered, something further to be learned in all its departments; something mysterious lies at the base of everything and invites investigation. What is gravitation, heat, electricity, life? By what means do substances act upon each other at a distance? Science shows no end, even in prospect, and it is a noble contemplation, that we have before us an ocean of boundless discovery, and that the domain of extension in science education, and consequently also in the moral, intellectual, and physical improvement of mankind, is practically unlimited.

The extension of science does not consist in pulling down other branches of learning, but in building up the fabric of verifiable truth. By developing new truths it incidentally exposes the fallacy of many of our dogmatic beliefs and superstitious opinions, but leaves those errors to fall of themselves; in this way it is fast changing our views of many things, and is becoming a great guide of human action and a foremost leader of human belief. It has already penetrated deeply, not only into all ordinary physical and chemical matters, manufactures, agriculture, medicine, and the art of war, but also into cosmogony, the constitution of the sun, distant worlds, and nebulæ. It is fast also bringing within the domain of experiment the relation of physical and chemical conditions to vital actions, the origin of species, and to the phenomena of mind itself. Even at the present time the realities of science far exceed in wonder the highest imaginations of the poets.

Scientific instruction consists but little in teaching tradition or dogmatic opinions; its great occupation lies in teaching veritable truths. It consists, not only in the teaching of words, but also of the tangible realities which those words represent, the forces and substances of the material world; the great beauty of science is the high degree of certainty of its results. "The sciences of matter are universally recognised as the most perfect examples of certain knowledge."

Science encourages a high morality. It bridles our vicious passions by showing us the penalties which must be paid for their indulgence; it moderates our self-conceit by shewing us the extremely limited extent of our faculties; it limits our self-will by shewing us that we *must* respect and obey the laws of nature whether we are willing or not—no man can improperly handle dangerous substances with impunity; it moderates our bigotry by showing us the great uncertainty of unprovable opinions; it restrains our credulity in men's assertions, by shewing us their frequent fallacy; it gives us confidence in the laws of nature, by shewing us their uniformity; it withdraws us from self-deception, by compelling us to accept the truths of nature as they exist ready made for us, whether they harmonise with our preconceived ideas or not. Men cannot argue with nature as they can with their fellow men, but *must* submit to her dumb eloquence of truth. In dogmatic subjects men may (and doubtless frequently do) unintentionally state untruths by authority or tradition, and no man can disprove them; but in veritable science a man speaks with caution, because his fellow men will soon put his statements to the test.

Probably nothing has a greater effect in making a man humble than a thorough knowledge of science. Hitherto man has been largely accustomed, through the force of superstitious opinion, and other causes, to view all nature as having been provided expressly for *him*, but science proves to us that man, and even the earth itself, is but a speck in creation; and that not only is the earth merely a planet revolving round the sun, but that the sun is only one of a multitude of suns, and is itself with all its planets circulating round a still more distant centre in space. To obtain an accurate acquaintance with science, it is absolutely necessary to set aside all human pride, and approach the subject with the deepest humility, like a little child. No other course is possible.

Scientific knowledge affords advantages to all classes of men: to the minister of religion, by supplying him with endless illustrations of the power of God, in the greatness, smallness, and perfection of nature; to the physician, by explaining to him more perfectly the structure and phenomena of the human body, and by providing him with new remedies; to the statesman and politician, by making known to him the great and increasing relations of science to national progress, by its influence upon wages, capital, the employment of workmen, the art of war, the means of communication with foreign countries, &c.; to the philanthropist, as an endless source of employment for workmen by the development of new discoveries, inventions, and improvements in arts and manufactures; to the military man, by affording him new engines and materials for warfare and defence; to the inventor, by supplying him with new discoveries upon which to found inventions; to the merchant and man of trade, by the influence of new products and processes upon the prices of his commodities; to the manufacturer, as a means of improving his materials, apparatus, and processes; to the investor of money, by assisting him to judge what technical schemes are likely to succeed.

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